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COUNTRY REPORTS ON THE PROGRESS MADE SINCE THE ELEVENTH CONFERENCE

The status of cartographic activities in the United States of America

Submitted by the United States of America

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THE STATUS OF CARTOGRAPHIC ACTIVITIES IN THE UNITED STATES OF AMERICA

INTRODUCTION

Since the Eleventh U.N. Regional Cartographic Conference for Asia and the Pacific, U.S. cartographic activities have expanded to include recent advances in computer technology, remote sensing, geographic information systems, and inertial and satellite positioning systems in support of surveying and mapping programs.

All phases of mapping and charting in the United States have been significantly influenced by the development and implementation of automated cartographic techniques and equipment. The application of computers to cartographic activities in the United States has included compilation, revision, maintenance and production of topographic, orthophoto, and image maps and aeronautical and nautical charts.

Advances in computer technology over the last 5 years have prompted Federal mapping and charting agencies to increase their efforts in building digital data bases of categories that are useful to the study of geology, soils, hydrology, land use, and land cover. A major achievement since 1984 has been the development and general acceptance of standards for digital cartographic data throughout the cartographic community.

The U.S. Geological Survey of the Department of the Interior has the domestic responsibility for preparing and making available multipurpose maps and base cartographic data in a variety of forms. In recent years, the U.S. Geological Survey has concentrated on digitizing base categories of data found on topographic maps, such as hypsography, hydrography, and transportation systems, to create a National Digital Cartographic Data Base. Other Federal agencies are responsible for collecting additional map data of public value. The National Ocean Service of the National Oceanic and Atmospheric Administration is responsible for geodetic surveys and for the preparation of aeronautical and nautical charts. The Defense Mapping Agency of the Department of Defense is responsible for the preparation of maps, charts and geodetic products on a worldwide basis to meet national defense requirements and for the preparation of nautical and aeronautical products to support safety of navigation.

The activities of these primary mapping and charting Federal agencies in the United States during the reporting period are discussed under the following headings:

- Geodesy
- Image Mapping
- Topographic Mapping
- Hydrography and Oceanography
- Aeronautical Charting
- Geographic Names
- Digital Cartography
- Global Change

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GEODESY

The National Geodetic Survey Division's (NGS) primary mission is to establish and maintain the National geodetic horizontal, vertical, and gravity networks which make up the National Geodetic Reference System (NGRS). Progress in improving the NGRS during fiscal year 1990 is described below.

Global Positioning Systems (GPS) Surveys and Applications

NGS continued the application of GPS to geodetic surveying, including the development of software packages, transfer of technology to other Government agencies and the private sector, and determination of precise GPS orbits for the surveying community.

The application of GPS technology, using signals from the satellites of the NAVSTAR system being established by the Department of Defense, continues to be an efficient, economical, and accurate survey system.

NGS completed GPS surveys with five Texas Instrument model TI4100, eleven Trimble Navigation model 4000ST, and five MACROMETER® model V1000 GPS satellite survey systems. The MACROMETER® and TI4100 receivers were retired and replaced during the year with ten Trimble Navigation model 4000SST GPS satellite survey systems.

NGS observed GPS satellite surveys in the vicinities of the Tangent Point to Colville River area, Alaska; the Loma Prieta Earthquake and the Salton Trough areas, California; York County, the South Edisto River Basin, and the Hurricane Hugo storm damaged areas, South Carolina; and in Alaska, Oregon and Washington for the purpose of statewide network upgrades. GPS surveys were also observed for the Departments of Transportation in Alaska, Florida, Michigan and Minnesota; the Nuclear Regulatory Administration; the Central Intelligence Agency; the National Crustal Motion Network project in Alaska and California; and seven projects in support of the Airport Datum Monumentation (ADAM) program of the Federal Aviation Administration.

In addition to NGS observed GPS surveys, 32 GPS survey projects were received from other agencies including: U.S. 431, Highway 55, Highway 278, Corridor X and the Montgomery Test, Alabama; Morgan Hill, Calexico to Thermal, Huntington Beach, Tulare County, Fresno/Monterey Counties and Butte/Tehama Counties, California; Delaware/Pennsylvania Boundary; Tallahassee/Leon Counties, Marion/Volusia Counties, State Route 40, U.S. Route 17 and Hillsborough County, Florida; Harford County Densification, Maryland; Muskingum County and the City of Cincinnati, Ohio; Route 138, Block Island Lighthouse and Network Densification, Rhode Island; Cherokee County, Georgetown, Greenville and Orangeburg County, South Carolina; Chatham County, Texas; York County and Westmarket/Prince William County, Virginia; and the City of Appleton, Wisconsin.

The projects completed were in support of varied requirements including: extension and densification of the National Geodetic Reference System (NGRS); monitoring of vertical and horizontal displacements associated with tectonic movements; monitoring crustal motion network stations and connecting Federal

Aviation Administration (FAA) airports to the NGRS; Global Mean Sea Level studies; state and county geodetic network and control survey upgrades; and state highway surveys. NGS observed the following projects between October 1989 and September 1990 using GPS surveying techniques:

Number of projects.....19
Number of receivers per project.....5/6
Total stations occupied.....2,244

NGS participated in tests and demonstrations of two GPS satellite surveying systems. These tests make a total of fourteen tests conducted since 1983 by the Federal Geodetic Control Committee (FGCC) on the FGCC test network located near Washington, D.C.

Use and enhancement of in-house GPS orbit computation software continues. Tracking data for fourteen GPS satellites are being routinely received from twelve Cooperative International GPS Network (CIGNET) and five Defense Mapping Agency (DMA) tracking stations throughout the world. The CIGNET data are prepared for archiving storage and distribution and are used with the orbit software package PAGE to compute precise GPS orbits. The DMA data are being used to check the results. This computational effort began the transition from the distribution of precise GPS orbits computed formerly by the Naval Surface Warfare Center and now by DMA to NGS-computed orbits for the civilian GPS user community. A planned April 1990 start for release of the CIGNET orbits was delayed until November 1990 because of the start of Selective Availability on the GPS satellites by the Department of Defense and its affect on orbit computation techniques and software.

Other fiscal year 1990 GPS satellite survey developments were as follows:

Operational kinematic GPS field units completed observations in support of the FAA ADAM program in Arkansas, Florida, Michigan, and Missouri. Plans are being developed to observe the FAA Loran C airport program in a similar manner.

The operational use of the GPS vector reduction package OMNI continued in the office and on two of the NGS GPS field units. The software package has been used successfully with data from four different GPS receivers and progress has been made with vector computations using mixed receiver combinations within the same observing session.

All NGS GPS field units are now capable of doing least-squares adjustments of field reduced vector data. Two of the four units carry out this analysis on a routine basis.

All orbit tracking data and computation results, office vector computations, field computations, and raw GPS observations are routinely archived on optical WORM (Write Once, Read Many) disks. This is significantly reducing the cost of storing the data, reducing the space required, and extending the projected usable life span of the storage media when compared with nine-track tapes.

U.S. Geological Survey (USGS): GPS surveying techniques have become the predominant means by which mapping control is established, and is playing an increasing role for geophysical surveys.

Point positioning techniques are used extensively in support of all National Mapping Division map control work and GPS is also being used in Antarctica to support a variety of scientific projects sponsored by the National Science Foundation. Kinematic collection methods have demonstrated significant gains in productivity. The most promising is the GPS-controlled aerial photogrammetric technique which is being tested for use in the revision of standard quadrangle maps.

The Geologic Division is using advanced GPS data reduction techniques to measure crustal deformation in tectonically active areas in the western conterminous U.S., Alaska, and Hawaii. GPS surveys will be used to establish new crustal monitoring networks and are being groomed to replace the Geodolite for existing networks. Deformation networks in the Long Valley Caldera and the San Francisco Bay area are currently being remeasured. Future biannual measurements of a number of 4-to-6 station Geodolite networks along the San Andreas fault will be made using GPS.

The Water Resources Division is using GPS surveys to establish control for Superfund sites and to determine the elevations of well heads for hydrologic studies. Projects include the Fork River EPA Superfund site in Butte, Montana, and the Ciba-Geiay site at Toms River, New Jersey. GPS survey systems were purchased in 1989 for use in the southeastern U.S. and will be shared by five district offices. Work also continues measuring the Sacramento, California, subsidence network.

Defense Mapping Agency (DMA): DMA continues to exploit the GPS for geodetic Purposes. DMA operates a worldwide GPS satellite tracking network and has established a computer facility for the generation of GPS precise orbits. Data from the DMA network and the Air Force GPS monitor stations are used for orbit generation. DMA has assumed full responsibility for generation of these orbits from the Naval Surface Warfare Center (NSWC) which was funded by DMA to develop the orbit reduction capability. The state-of-the-art program for orbit generation is called OMNIS which uses Kalman filtering and smoothing techniques. DMA has developed a GPS absolute positioning capability, and has procured relative positioning software.

Technology Transfer

National Geodetic Survey (NGS) headquarters office personnel again trained NGS field personnel as well as employees of other Federal agencies in the use of microcomputers and GPS vector computational procedures. Two 3-week training sessions in GPS technology were conducted for employees of the Bureau of Land Management (BLM), the Forest Service, and the Bureau of Reclamation. Under provisions of a formal Memorandum of Understanding, NGS is assisting BLM offices in their implementation of GPS for cadastral survey applications.

GPS technology transfer was also supported by participation in panel discussions, technical papers, speeches and the training of scientists and

surveyors visiting NGS, both national and international. NGS continues to be an international focal point for GPS field work, development, and information. NGS is committed to the continued development of GPS as the primary surveying system for both the public and private sectors.

NGS continued to coordinate development of Multipurpose Land Information Systems: The Guidebook. The first release (Chapters 1 through 3) was published in February 1990; the second release (Chapters 4 through 7) in October 1990.

The National Oceanic and Atmospheric Administration (NOAA) state geodetic advisory program is a cooperative 50/50 cost-sharing program between Federal and State governments. NOAA assists the States with their charting, geodesy, and surveying programs, suggests maintenance functions, ensures that surveys performed by the States meet Federal standards and specifications, and helps in the transfer of new surveying technologies.

Horizontal Geodetic Network

The final report of the North American Datum of 1983 (NAD 83) project was printed. Horizontal geodetic adjustments are now computed on SUN work stations. Graphics are being developed to analyze the new observations against the existing network. All in-house computers retrieve data from the NGS Integrated Data Base. Results of the computations are stored in the data base within 1 month of completion.

Processing of horizontal data into NAD 83 continued with new Global Positioning System projects and classically observed projects. The current backlog consists of 368 projects containing 20,150 stations. An additional 84 projects consisting of 5,745 stations are in progress. In the past year, 115 projects containing 13,350 stations were completed.

Cooperative efforts to provide horizontal control were conducted in Florida, Alaska, Oregon, Michigan, and York County, South Carolina. Special projects were conducted in the natural disaster areas of the Loma Prieta earthquake in California and Hurricane Hugo in South Carolina.

The cooperative efforts in the States of Florida, Tennessee, and Oregon involve high accuracy (one part in 1,000,000) global positioning surveys. The development of high accuracy vector reduction techniques and network adjustment analysis has lead to a new policy on integrating these results with the existing NAD 83 network.

To aid users of geodetic data, development was completed on a datum transformation technique between NAD 27 and NAD 83. The Corps of Engineers adapted this new North American Datum CONversion (NADCON) program to use and produce State Plane Coordinates and Universal Transverse Mercator coordinates.

NGS continued to provide the Federal Aviation Administration with horizontal control at 1,400 airport facilities. These airports have instrument approach procedures but no obstruction control surveys. During the last year, datum tie observations were made at 269 airports. Final coordinates were computed

for 191 airports. Since the beginning of the project, coordinates have been computed for 914 airports.

Transfer of technology to State, county, and private surveyors and engineers continues to be an increasingly important activity within NGS. Two 1-day Coordinate Transformation Workshops and three 1-day Use of the State Plane Coordinate System Workshops were presented through co-sponsorship with the American Congress on Surveying and Mapping.

Another aspect of the vertical control effort, the definition of a new vertical datum, will define the new reference surface on which to base the improved geodetic heights. The datum definition effort requires consideration of all agencies that will be impacted, including the U.S. Army Corps of Engineers, Defense Mapping Agency, Department of Energy, Federal Emergency Management Administration, U.S. Geological Survey, and State and local users. Meetings will be held with each interested agency and their requirements will be considered in the datum definition decision.

Post-NAD 83 Regional Adjustments

Due to the excellence of results obtained from GPS-based interferometric geodetic surveys, and due to the lower costs involved in making GPS surveys, states are considering the upgrade of their horizontal geodetic control networks by means of statewide, high precision GPS surveys in support of mapping, civil engineering projects, and land information systems.

The cooperative efforts in the States of California, Colorado, Florida, Maryland, Tennessee, Oregon, Wisconsin, Washington, and New Mexico involve high accuracy (one part in 1,000,000) Global Positioning surveys. Organizations in Delaware, Idaho, Montana, Utah, Virginia, and Wyoming are actively considering similar upgrades. The development of high accuracy vector reduction techniques, and network adjustment analysis has lead to a new policy on integrating these results with the existing NAD 83 network.

Vertical Geodetic Network

The New Adjustment of the North American Vertical Datum of 1988 (NAVD 88) continued with the NGS counterpart agencies in Canada, the Geodetic Survey Division (GSD) of the Canada Centre for Surveying, and Mexico, the Instituto Nacional de Estadistica Geografia e Informatica (INEGI). During fiscal year 1990 international cooperation was enhanced by technical exchange meetings, exchange of leveling data, and continued joint investigation of several technical and research areas involving NAVD 88. Completion of the primary phase of the new adjustment is scheduled for December 1990, with publication of resulting heights during 1991-92. Some of NOS' accomplishments in support of the new adjustment associated with NAVD 88 are highlighted in the following table:

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Accomplishment	FY 1990	Total to Date	Total Program
New NAVD leveling surveys performed (kilometers)	2,225	81,160	81,500
New leveling surveys processed (kilometers)	11,200*	137,700	138,500
Helmert blocking (data cleansing) performed (no. of blocks)	68	68	101

* Includes both NGS and non-NGS surveys.

The vertical control portion of the National Geodetic Reference System (NGRS) was strengthened by field survey projects in support of the NAVD 88 readjustment program, cooperative leveling projects, and leveling by State and county organizations. These surveys were accomplished primarily by NGS field units, U.S. Geological Survey (USGS), Metropolitan Water District of Southern California, New Jersey Geodetic Survey, North Carolina Geodetic Survey, Los Angeles Municipal Government, Imperial and Ventura Counties, California, Florida Department of Transportation, Minnesota Department of Transportation, and Mississippi Highway Department.

Cooperative surveys involving NGS field and office personnel (cooperating organizations in parentheses) included:

1. Densification of vertical control in Harford County, Maryland, (Harford County);

2. Establishment of heights above mean sea level for bench marks used to determine deflection of the vertical by combining leveling and GPS data, Colonial Beach, Virginia (Naval Surface Warfare Center);

3. Vertical control for the Interstate highway system in the vicinity of Omaha, Nebraska (Nebraska Department of Roads);

4. Leveling to support GPS surveys in the Coeur D'Alene area, Idaho, (Idaho Transportation Department);

5. Vertical control densification in Wicomico County, Maryland, (Maryland State Highway Administration, Federal Highway Administration, and Wicomico County Public Works);

6. Leveling to determine vertical deformation caused by the Loma Prieta earthquake in California (USGS);

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7. Reestablishment of base lines along the South Carolina coast after Hurricane Hugo (South Carolina Coastal Council); and

8. Reestablishment of vertical control for Santa Cruz County, California, following the Loma Prieta earthquake (Santa Cruz County).

Several research activities are underway in support of the New Adjustment of NAVD 88. These include: crustal motion effects and models; and orthometric heights derived from GPS ellipsoidal heights and gravity data.

Research in support of the redefinition of the International Great Lakes Datum (IGLD) included: updating all water level transfer data from both Canada and the United States into NGS' data base; processing and loading a portion of the Canadian leveling network into NGS' data base; performing and analyzing special adjustments combining Canadian and U.S. water level transfer data and leveling data; and performing check leveling to detect data outliers in the leveling data.

With the completion of the majority of the NAVD 88 releveling program, NGS' Vertical Network Branch has undertaken a special study to compile a primary vertical control network using the latest data available. This network consists of 202 loops containing 903 junction bench marks. The network connects to 58 primary tidal stations which are part of the National Primary Tidal Network and 26 water level stations along the Great Lakes. In addition, 26 connections were made to the Canadian vertical control network and 14 to the Mexican vertical control network. All geopotential differences have been generated and validated, using actual gravity values. Loop closures were computed, a least-squares adjustment performed, and data outliers were detected and removed. Adjustments imposing various datum definition scenarios have been performed.

The results of the study have been documented. The report has been reviewed by NGS, Canadian GSD, and Mexican INEGI personnel. Meetings were held to discuss and analyze the results. In addition, a list of U.S. agencies' products and services affected by NAVD 88 and a preliminary NAVD 88 implementation plan have been drafted. A FGCC Vertical Subcommittee has been meeting periodically to determine and document the impact of NAVD 88 on users.

Several technology transfer activities were directed toward State, local, and private surveyors and engineers. A 2-day Vertical Control Workshop was presented in Seattle, Washington. Several other workshops, including those covering geographic information systems, coordinate computation, and coordinate transformations were coordinated through the Vertical Network Branch of NGS.

Gravimetric Network

The Space and Physical Geodesy Branch of NGS is responsible for the relative gravity program and the Geodetic Research and Development Laboratory is responsible for the absolute gravity program.

Relative Gravity Program: NGS maintains a gravity data bank containing approximately 1.8 million observed gravity records. This data bank was extended by the addition of 185,000 gravity point values in the Mexico region obtained from the University of Texas at Austin. These data will strengthen the geoid definition in the south west conterminous United States (CONUS).

Observation records of the gravity data bank were transferred into the NGS Integrated Data Base resulting in better use of this essential resource and improved data integrity and security. The gravity data holdings of NGS were recently furnished to the National Geophysical Data Center in Boulder, Colorado, where they have been included in a compact disc "read-only medium" (CD-ROM) for efficient dissemination to users.

A new NGS product in the form of interpolated gravity was made available to the public. These gravity values are derived from observations; they are frequently requested for the calibration of various instruments which are affected by the local variations of the gravity field.

Geoid height values were also derived from GPS-determined ellipsoid heights and measured orthometric heights (i.e. obtained from leveling). Systematic deviations of gravimetrically derived geoid heights from GPS-leveling determined values were estimated via least-squares techniques. The fitting of gravimetric geoid to the GPS framework by the removal of systematic differences facilitates the densification of orthometric heights. Orthometric heights derived by these techniques are being used for vertical control in aerial photogrammetry.

Numerical techniques were investigated for the estimation of accurate gravity values for the NAVD 88 network adjustment. A weighted least-squares technique provided acceptable accuracies in interpolated gravity where dense observed gravity values were available. However, the estimated accuracies were judged to be inadequate in sparsely covered areas. Another technique, employing the multi-quadratic model of Hardy, provided accurate and reliable values in all geographic areas in the CONUS and was adopted for interpolating gravity at the 900,000 bench mark stations of the NAVD 88 datum.

The cooperative project between the Geophysics Division of the Geological Survey of Canada and NGS was continued. The optimal application of the Fast Fourier Transform method to gravity field modeling was investigated. Results of these investigations were accepted for publication in the Bulletin Geodesique journal.

Absolute Gravity Program: The JILAG#4 absolute gravity instrument has been used to monitor gravity changes associated with vertical crustal motion under the NOAA Climate and Global Change Program. Twelve stations were occupied during the year, including observations during the Third International Comparisons of Absolute Gravimeters in Sevres, France, and the establishment of reference gravity values in Wettzell, Germany, and Edinburgh, United Kingdom. Since the measurement program started in April 1987, approximately 85 gravity determinations at about 50 sites have been accomplished.

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The instrument underwent testing and modifications during the year, and new data collection and analysis procedures have been developed. Part of the modifications and new procedures served to largely eliminate the effect of systematic floor vibrations on the measurements. A floor-gravimeter system response correction of +16 microgal was computed and added to the data at Wettzell, strongly suggesting that some of the large differences noted among the observations of absolute gravity by different instruments at the same sites could have been due to their different response to systematic vibrations. Due to these improvements, the scatter about the mean of the absolute gravity values at repeated sites has been reduced to 2 microgals or less.

The superspring assembly modifications included the addition of restraints allowing transportation of that component as regular cargo without damage, and the installation of a temperature compensating circuitry eliminating data loss due to bottoming of the superspring mass. Designs for both of these modifications were obtained from the Canadian Geological Survey.

Geodetic Astronomy

The Defense Mapping Agency (DMA) provides Geodetic and Geophysical support to the United States Department of Defense (DoD). DMA is involved in satellite geodesy, gravity collection and evaluation and determination of world geodetic systems.

World Geodetic System 84 (WGS 84)

DMA produces numerous mapping, charting, geodetic, gravimetric and digital products in support of Department of Defense. It is advantageous to refer these products to a single geocentric coordinate system for many reasons. Such a system is needed due to accuracy and user interface considerations; the need for a product to support the widest possible range of applications (local, worldwide); the need to relate information from one product to data obtained from another source; and the need to ensure a smooth transition in product use from one part of the world to another. In accomplishing the preceding, such a geocentric system, termed a world geodetic system, provides the basic reference frame and geometric figure for the earth, models the earth gravimetrically and provides the means for relating positions on various local geodetic systems to an earth-centered, earth-fixed (ECEF) coordinate system. In brief, a world geodetic system serves as the framework for DMA products and worldwide DoD operations.

National Geodetic Information Center

This branch of NGS distributes geodetic information products to satisfy current and anticipated user requirements. These products include the results of geodetic surveys, software programs to compute, verify, and adjust original survey observations, and publications describing how to obtain and use geodetic data and application products. The branch also conducts a marketing program to increase user awareness and understanding of these products, and to improve NGS' responsiveness to its users.

As part of its marketing program, NGS accomplished the following:

Conducted workshops on how to obtain, understand, and use NGS information products;

Displayed and described NGS products, services, and program activities at more than 20 symposia and professional society meetings throughout the United States;

Distributed Lambert projection tables for the State Plane Coordinate System of 1983, allowing users with a minimum of computing resources to compute State Plane Coordinates from NAD 83 geographic coordinates;

Prepared for distribution of a detailed report describing the redefinition and adjustment of NAD 83;

Provided users with new publications and software products to help them understand and use coordinate systems based on NAD 83;

Distributed new software called VICES (VIsual Cartographic Enquiry System) that allows users to plan a survey by easily retrieving and displaying control point and map name information;

Conducted cost studies to ensure that the prices for all NGS information products are consistent with agency pricing guidelines and reflect only the costs of duplicating and distributing these products;

Implemented an automated sales tracking system that prints invoices, mailing labels, and a daily log of orders; verifies the prices for all information products distributed; and prepares sales statistics for periodic reports and management decisions;

Provided numerous publications, historical records, and the results of research investigations in order to fulfill diverse requests from universities, individuals, Government agencies, and businesses throughout the United States and from other countries.

In addition, NGIC undertook the following steps to improve the quality and availability of geodetic data:

Began a contract with Management Technology, Inc., to update and automate the backlog of approximately 100,000 station recovery notes;

Implemented improved station description processing procedures; also implemented was the Description Integration System, a way to unify all description tables in the NGSD Integrated Data Base;

Prepared to consolidate data distribution from two locations to one;

Submitted a proposal for a unified data sheet to replace separate data sheets for horizontal and vertical control points;

National Ocean Service (NOS) GEOSAT Altimeter Program

Prior to its failure in October 1989, the GEOSAT altimeter produced approximately 750,000 global observations of sea level over a 5-year period. Throughout this time, NOS played a critical role in three areas of the mission: production of data sets for public distribution, near-real-time monitoring of tropical sea level, and climate research.

Under agreement with the U.S. Navy, NOS produced the GEOSAT data sets (known as Geophysical Data Records or GDRs) in Rockville by combining the raw measurements with a precise orbit, a tide model, and radar path length corrections for delays due to troposphere and ionosphere. GDRs are distributed to the public through NOAA/NESDIS and reached the user within 2-3 months of acquisition during the mission, remarkably fast turnaround for a global satellite data set. Nearly 40 institutions around the world purchased subscriptions to the GEOSAT data.

In addition to processing the data for public distribution, NOS has developed a program of tropical sea level monitoring. The GEOSAT data are processed to derive sea level change as a function of time, much like island tide gauge data. During the 1986-87 El Nino, NOS was able to monitor sea level changes throughout the tropical Pacific in near-real-time, the first time this had even been accomplished. An operational sea level bulletin for the tropical Pacific, Atlantic, and Indian Oceans was produced on a monthly basis and distributed to nearly 2,000 users worldwide.

Research is performed not only to interpret tropical ocean changes seen by GEOSAT but also to improve accuracy. This involves incorporation of new satellite ephemerides and tropospheric corrections fields and algorithm development. Accuracy can be assessed by comparison with island tide gauges and with results of wind-driven numerical models. For large-scale sea level changes, GEOSAT has been shown to be reliable at the sub-centimeter level. This has enabled construction of the first detailed descriptions of sea level change in the three tropical oceans, and the first complete altimetric observation of El Nino.

NOAA's altimeter program will continue with the launch of European Space Agency Remote Sensing Satellite (ERS-1) in April 1991. ERS-1 is an operational satellite which will offer access to most of its global data within 3 hours of acquisition. Additional altimeter observations to support NOAA's tropical sea level monitoring program will be available from NASA's Topographic Experiment (TOPEX) in 1992. Each of these missions is expected to last 3-5 years, providing continuous altimetric coverage well into the 1990's.

Marine Geodesy and Geodynamics

As in the previous year, altimeter data from the GEOSAT Exact Repeat Mission (ERM) are also being used to map the marine gravity field for geodetic and geophysical purposes. Starting with the GDR's which are produced by NGSD, multiple repeat cycles are averaged together to produce precise, high-resolution profiles of along-track geoid undulations and deflections of the vertical. Such profiles have been derived from the first 2 years (44 cycles)

of ERM data, in cooperation with Dr. D. T. Sandwell of the Scripps Institution of Oceanography. Within the past 6 months, improved along-track profiles have been derived using the much more precise GEM-T2 orbits in place of the operational NAG orbits. Comparisons between these along-track profiles and SEABEAM (swath sonar) maps of seafloor along particular ERM groundtracks have been made. These comparisons indicate that the resolution of these along-track altimeter profiles is quite high.

The U.S. Navy has just declassified and released the previously classified GEOSAT Geodetic Mission (GM) data for the Antarctic (i.e., all latitudes between 60 and 72 degrees South). Final preparation and verification of these GM GDRs are now being performed at NOS. These GM GDRs will be distributed to the public soon through NOAA/NESDIS. The GM groundtracks are much more tightly spaced than the ERM groundtracks; therefore, these GM data should yield a very high resolution mapping of the marine geoid and gravity field around the margin of Antarctica. If and when GM data are released for other regions, similar high-resolution mappings will be possible for these other regions. If these GM data do not become available for other regions, then the European Space Agency's Remote Sensing Satellite (ERS-1) altimeter data will be used to produce accomplish these high-resolution mappings of the marine gravity field.

National Ocean Service (NOS) Very Long Baseline Interferometry Program

The NOS Very Long Baseline Interferometry (VLBI) observatories continued to participate in the IAG/COSPAR jointly sponsored International Radio Interferometric Surveying (IRIS) Earth orientation monitoring program. The IRIS Earth orientation parameters (EOP) time series are currently the most accurate and stable available. Polar motion (X, Y) values accurate to 1-2 milliseconds of arc at 5-day intervals, UT1 values accurate to 0.05-0.10 milliseconds at 5-day intervals and 0.1 milliseconds at daily intervals are produced routinely. The 5-day observations are also used to estimate corrections to IAU 1980 nutation time series, and to study crustal deformations, develop celestial and terrestrial reference frames, and for other scientific research.

Four antennas operate once every 5 days for a 24-hour period. Three of these are located in the United States: Westford, Massachusetts; Richmond, Florida; and Mojave, California. The fourth antenna is located at Wettzell, Germany, operated by the Institut fuer Angewandte Geodasie. A fifth antenna at Onsala, Sweden, joins the network once a month.

The Mojave and Richmond Observatories also participate in monthly IRIS-P observing sessions organized by the Mizusawa Latitude Observatory, Japan.

The IRIS EOP time series are published monthly in IRIS Bulletin A (more than 300 copies are distributed to users in approximately 40 nations) and are available in machine-readable format from NGS.

The geodetic astronomy program includes daily monitoring of variations in UT1. This effort involves the Westford and Wettzell antennas operating for an hour a day.

In October 1989, NGS loaned a Mark lII terminal to the University of Tasmania, Australia, for use at the Hobart Observatory. The observatory is participating in IRIS-S, IRIS-P, and NASA Crustal Dynamic Project (CDP) observing sessions, totaling thirty 24-hour sessions per year.

Beginning in November 1989, NGS loaned, on a long-term basis, a Mark III data acquisition terminal to the Hartebeesthoek Observatory, South Africa, for VLBI observing campaigns involving stations in North America, Europe, Africa, and Australia. Observing sessions are scheduled twice per month. Joint observations with the new observatory in Hobart, Australia, have already allowed NGS to extend the celestial reference frame to global coverage.

An agreement was signed by NGS and a consortium of geodetic agencies in Brazil, headed by the University of Sao Paulo, to develop a new VLBI observatory at Fortaleza, Brazil. NGS obtained a 17-meter radio telescope from the National Science Foundation for redeployment at the new station, and a new data acquisition system including a VLBI type terminal and H-Maser is being purchased. Plans are to complete the observatory by the end of 1990.

The mobile VLBI unit, MV-3, was deployed to Europe from May to September 1989, to densify the geodetic control network. A total of six stations in the Germany, Finland, Norway, United Kingdom, and France, were visited. The observations achieved centimeter level accuracy, providing excellent fiducial sites for GPS surveys in Europe.

Work continued on the Cooperative International GPS Network (CIGNET). New NGS receivers were installed at the Hobart, Australia, VLBI observatory and in Wellington, New Zealand. Additional sites will be added in 1990 to complete the Australian-New Zealand Network referred to as the "Southern Cross."

IMAGE MAPPING

Remotely sensed image products have been recognized as valuable mapping tools, map supplements, and alternatives to standard maps by mapping agencies in the United States. Today, image maps are utilized as interim substitutes for line maps and as final products that incorporate detail not easily conveyed by line map symbolization. To provide source materials, programs have evolved in high-altitude photography, orthophotography, satellite imagery, and side-looking airborne radar.

The National Aerial Photography Program

The National High-Altitude Photography Program, managed by the U.S. Geological Survey, began in 1980 to acquire 1:80,000-scale black-and-white and 1:58,000-scale color-infrared photography from a flying height of 40,000 feet (12.2 kilometers). This program was completed in November 1988, and uniform coverage of the conterminous United States is available from the archives of the U.S. Department of Agriculture, Aerial Photography Field Office, in Salt Lake City, Utah, and the U.S. Department of the Interior, U.S. Geological Survey, in Sioux Falls, South Dakota.

The National High-Altitude Photography Program is a recognized success. It revealed a growing national interest in high-resolution, color-infrared photography for a wide variety of applications, such as agriculture, forestry, soils, land and resource management, mapping, and numerous earth-science applications, that require higher resolution than the program provided. As a result of this interest, Federal and State agency users agreed to establish a new program called the National Aerial Photography Program (NAPP). The new program, also under U.S. Geological Survey management, began in 1987. Photography under the new program is acquired from a flying height of 20,000 feet (6.1 kilometers) with a single 6-inch (15.2 centimeters) focal length camera exposing color-infrared film or black and white at a scale of 1:40,000. The resulting photographs are centered on quarter sections of standard U.S. Geological Survey 1:24,000-scale, 7.5-minute quadrangles. The ground resolution of photography is 1.0 to 1.5 meters, depending on contrast of the terrain.

The first 5-year cycle for the program will be complete after the fiscal year 91 flying is accomplished. A second cycle called NAPPII will begin in 1992. To date, about 65 percent of the lower 48 States have been contracted. The NAPP II promises to continue this vital National program on behalf of the contributing State and Federal agencies and the user public for the good of the country.

Orthophotography

Orthophotoquads portray land features on photographic images that have been processed to show surface detail in true position. Orthophotoquads do not include contours and are printed in shades of gray without image enhancements or cartographic symbolization. The demand continues for orthophotoquads to support numerous planning and resource management activities as companion maps to published topographic maps. Approximately 38,000 orthophotoquads have

been produced by the U.S. Geological Survey and are available either as diazo or photographic reproductions. During this reporting period, the U.S. Geological Survey prepared approximately 6,700 orthophotoquads at 1:24,000, 1:;12,000, and 1:63,360 scales.

Special purpose orthophotoquads have been produced with enhanced color portrayal of the terrain and selected cartographic symbolization. The U.S./Mexico Border Mapping Project, conducted by the U.S. Geological Survey in collaboration with the U.S. Customs Service, the International Boundary and Water Commission, and the Direccion General de Geografia of Mexico, was completed during the reporting period. All 211, 1:25,000-scale photoimage maps of the U.S./Mexico border are now published.

Satellite Image Mapping

The U.S. Geological Survey has developed routine production techniques for preparing satellite image maps from Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM) data and data from the French Satellite pour l'Observation de la Terre (SPOT). These techniques include digital image enhancement, image mosaicking, and methods for graphic image preparation and lithographic printing. Using these techniques, sixteen 1:250,000-scale image maps were printed from Landsat MSS data, four 1:100,000-scale image maps were printed from Landsat TM data, and two image maps were printed from SPOT data for areas in the United States. Image maps were produced for a number of foreign areas, including portions of Saudi Arabia, Jordan, United Arab Emirates, Kenya, Argentina, and Antarctica.

A significant improvement was made in image enhancement for image mapping through the development of digital image restoration (deconvolution) software. Images processed using the restoration software as part of geometric rectification are both visibly sharper and of higher radiometric fidelity than those rectified without the procedure. Restoration improves image quality by removing sensor-introduced degradations, such as optical blurring and electronic signal smearing. This technique, which was developed by the University of Arizona under contract to the U.S. Geological Survey, is now applied during the image map preparation process to data from the Landsat MSS and TM, SPOT, and Advanced Very High Resolution Radiometer sensors.

The U.S. Geological Survey also implemented new spatial filtering enhancement procedures during the reporting period. This procedure is considered an optional step, dependent on subject detail and the intended use of the final product. Sometimes referred to as a boxcar spatial filter, it may be used either to modify low-frequency spatial data to increase the effectiveness of the contrast enhancement process, or to modify high-frequency spatial data to provide edge enhancement. It can also be used for preprocessing and noise removal.

Techniques have been developed for combining satellite image data sets possessing different spatial and spectral characteristics. The majority of this work has centered on combining 30-meter resolution Landsat TM multispectral data and 10-meter resolution single-channel SPOT panchromatic data. This process creates an image that has the spectral information from the TM

multispectral data and the 10-meter spatial resolution of the SPOT data. To demonstrate this capability, a multi-image display of satellite images of the Phoenix, Arizona, area was printed to show Landsat MSS and TM data, SPOT panchromatic and multispectral data, and Landsat TM and SPOT panchromatic data merged and presented at various scales. This lithographed display also shows portions of a standard U.S. Geological Survey orthophotoquad and a topographic quadrangle for comparison with SPOT panchromatic data, all at the scale of 1:24,000.

These data merging techniques were used to produce a Landsat TM/SPOT image map of the Viedma, Argentina, area, which is a candidate site for relocating Argentina's national capital. This image map was printed at 1:50,000 scale by the U.S. Geological Survey and the Instituto Geografico Militar of Argentina under the auspices of the Pan American Institute of Geography and History. A 1:50,000-scale SPOT image map of the Washington, D.C., area also was prepared by merging and mosaicking SPOT multispectral and panchromatic data, and a Landsat TM/SPOT merged image map was produced for Al Ayn, United Arab Emirates, using these techniques.

A 1:250,000-scale image map of the Denali National Park and Preserve, Alaska, was prepared and published using data from nine Landsat MSS scenes. Mount McKinley in Denali National Park has perhaps the greatest relief of any land mountain in the world, rising over 5,000 meters above its surrounding base. Although the Denali map did not have relief displacement removed, distortions due to relief displacement were minimized by modifying ground control points according to their elevation and location from satellite nadir to place control at a common elevation. This image map was also printed on plastic material to withstand repeated foldings and exposure to moisture during outdoor use.

The 1:125,000-scale Great Salt Lake and Vicinity, Utah, image map was produced using Landsat TM data to show the lake at its highest level since 1873. The large expanse of water in the image map posed special problems for image enhancement as the histogram standard deviation of each band of data was too large to allow adequate contrast enhancement of both water and land features at one time. This problem was overcome by digitally extracting the water area from the land, enhancing the data for each cover type separately, and then combining the data prior to lithographic reproduction. The final product contained land detail from TM bands 2, 3, and 4 and water detail from TM bands 1, 2, and 4.

Significant progress was made in enhancing and mosaicking Advanced Very High Resolution Radiometer data. Data from 15 images acquired between May 1984 and May 1986 were used to produce a false-color composite image of the conterminous United States. This image will be printed as a satellite image map at a scale of 1:7,500,000 during 1989. This type of product is especially useful for studying regional landscape patterns. It would have high value for natural resource assessment in developing countries where systematic map coverage and resource information are not available.

Side-Looking Airborne Radar (SLAR)

The U.S. Geological Survey originated the Side-Looking Airborne Radar (SLAR) program in 1980 as a result of a Congressional request "to begin the use of side-looking airborne radar imagery for topographic and geologic mapping, and geologic research surveys in promising areas." Since the program began, SLAR data have been acquired for approximately 40 percent of the United States.

Each mission is designed with regard to local geology and specific earth science research criteria for the area. Both high- and low-depression angle data are collected. Low angle data accentuates low topographic relief and subtle geologic structure while high angle data are usually preferred in mountainous terrain. SLAR also has the ability to penetrate most clouds, hence it is a nearly all weather system.

These SLAR data are available in both strip form and mosaicked onto 1:250,000-scale quadrangle format. Since 1986, computer compatible digital tapes have also been available. Beginning in 1990, all data acquired will also be available on CD-ROM's.

GLORIA Sonar Image Mapping

Over the past 9 years, the USGS and the British Institute of Oceanographic Sciences (IOS) have been involved in a cooperative program to collect, process, and analyze sonar images of the ocean bottom. The side-scan sonar images have been collected by the GLORIA (Geological Long Range Inclined ASDIC) system, which was designed, built, and is operated by IOS.

GLORIA was first used in 1979 to collect sonar images of selected areas along the U.S. Atlantic coast. These data were recorded only in analog format, but some digital processing was used on a few negatives. Several sonar-specific, preprocessing algorithms were developed to remove shading and geometric problems. In 1982, the Geological Survey and IOS collected GLORIA sonar data in the Gulf of Mexico, including digital image data on computer-compatible tapes. Only selected subsets of these data were processed, but new algorithms were designed and added to the preprocessing software package. In 1984, GLORIA data were collected off the west coast covering the newly declared Exclusive Economic Zone (EEZ). Due to the increased volume of data collected and the high interest in the EEZ, software to process the GLORIA data was refined, expanded and made operational on the Mini Image Processing System (MIPS). The 1984 west coast data were digitally processed and photomechanically mosaicked to generate 33 2- by 2-degree sheet mosaics. These mosaics and other data sets were published in atlas form in 1985.

During the summer of 1985 new data were collected for the remainder of the Gulf of Mexico EEZ, areas north and south of Puerto Rico, and the extreme southern portion of the Atlantic coast. These data from the Gulf and Puerto Rico and the 1982 data were digitally processed in strip form and then digitally mosaicked into 25 2- by 2-degree map sheets cast on a specified map projection. The 2-degree maps were subsequently digitally mosaicked into large area index map sheets. Both the 2-degree sheets and the index maps were published in 1987 in a Gulf of Mexico GLORIA atlas, and released on CD-ROM

disc. Geologic interpretations and seismic and magnetic profiles were an integral part of the Atlas.

Data collection has been completed in the EEZ off the U.S. East Coast, and in the Alaskan area, and Gloria atlases have been published for both the East Coast and Bering Sea. In addition, the East Coast and Bering Sea data have been released on CD-ROM. The Hawaiian EEZ will be completed in 1991. In 1991, mapping of the deep water EEZ around the 50 States will be completed, comprising approximately 2 million square nautical miles of sea floor. In addition, the EEZ mapping program will focus during 1991 on the EEZ around the American Flag Islands of the central and western Pacific Ocean, starting with the Johnston Island and Palmyra Atoll areas.

TOPOGRAPHIC MAPPING

Topographic mapping in the United States (50 States, U.S. Territories, and outlying areas) is the primary responsibility of the U.S. Geological Survey.

The principal cartographic activities of the U.S. Geological Survey can be related to the types of conventional map products--1:20,000-scale (Puerto Rico), 1:24,000-scale, and 1:25,000-scale, and 1:63,360-scale (Alaska) topographic maps, 1:24,000-scale and 1:63,360-scale (Alaska) orthophotoquads, and 1:100,000- and 1:250,000-scale regional maps. There is also significant activity in land use and land cover mapping at 1:100,000 and 1:250,000 scales, in State and national small-scale base maps, and in a variety of special maps including image maps prepared from high-altitude aircraft and satellite data.

The primary maps include the following categories of base map data: reference systems, hypsography, hydrography, vegetative cover, cultural features, boundaries, transportation systems, geodetic control, survey monumentation, and geographic names.

Because of newly defined mapping requirements and the development of new mapping, remote sensing, and photographic techniques, the U.S. Geological Survey has reorganized its cartographic and geographic activities and expanded its product lines. The following is a synopsis of progress by major categories.

Primary Mapping and Revision

During the reporting period, 3,350 new standard topographic maps were completed in the 7.5-minute, 1:24,000-scale series and the 1:63,360-scale series in Alaska. At the end of the reporting period, topographic map coverage at 1:24,000 scale (1:63,360 in Alaska) was complete for all States with the exception of small areas in Alaska.

These maps are periodically reviewed for revision with emphasis on changes in urban areas, coastal zones, airports, and other high national interest areas. Since September 1987, 3,600 primary quadrangle maps have been revised and published.

Intermediate-Scale Mapping

Intermediate-scale mapping at scales ranging from 1:50,000 to 1:100,000 continues to be a growing part of the U.S. Geological Survey's National Mapping Program. With the expanding interest in energy and mineral development and Federal land management, the demand for quadrangle maps at 1:100,000 scale has increased. Presently, intermediate-scale maps in quadrangle format are available or under production for the entire conterminous United States. During the reporting period, the U.S. Geological Survey produced 994 intermediate-scale maps.

Small-Scale Mapping

Topographic map coverage of the United States is complete at 1:250,000 scale, totaling 635 sheets. The series is currently maintained by the U.S. Geological Survey. In 1987, the U.S. Geological Survey implemented a new revision policy to replace the existing series with an updated series in side panel/metric format, prepared from paneled reductions of 1:100,000-scale topographic quadrangles. Digital terrain data for the 1:250,000-scale map series are available.

Other small-scale maps at 1:500,000 and 1:1,000,000 scale include State base maps and International Map of the World series.

Special-Purpose and Thematic Mapping

Special-purpose maps are prepared from existing map bases and information collected from various sources to meet the expressed needs of Federal, State, and regional agencies. Maps of national parks, monuments, and historic sites, produced by the U.S. Geological Survey at various scales for the National Park Service, are examples of special maps. Additionally, various thematic maps emphasizing a single topic or theme, such as geology or hydrology, are also prepared and published by the U.S. Geological Survey for the Government and scientific community.

The U.S. Geological Survey continues to support the U.S. Antarctic Program by conducting geodetic ground surveys and compiling topographic maps of the continent. To date, 95 1:250,000-scale maps of Antarctica have been published, as well as topographic maps at 1:50,000 scale, 1:1,000,000 scale, and smaller, and Landsat image maps at several scales.

Land Use and Land Cover Mapping

The U.S. Geological Survey continues its involvement in preparing land use and land cover products for the United States. The program provides the only systematic inventory of land use and land cover data that is nationwide in scope and features a uniform classification system portrayed at standardized scales. The maps and digital data are used by both governmental and private sector users to support a variety of resource management, planning, development, environmental monitoring, and geographic information systems activities.

Completion of land use and land cover and associated maps, primarily at 1:250,000 scale, for the conterminous United States and Hawaii was accomplished in 1987. The associated maps include political units, hydrologic units, and census county subdivisions as standard products; Federal and State ownership overlays were prepared under some State cooperative programs.

The graphic products are being digitized and the data are distributed by the U.S. Geological Survey in both vector and composite-theme grid cell format. Statistical summaries by quadrangle are also available. About 85 percent of the land use and land cover graphics for the conterminous United States and Hawaii have been digitized, with series completion scheduled for 1992. Pilot

projects to update the graphic and digital products using advanced cartographic systems, possibly at 1:100,000 scale, are underway.

Since 1978, the U.S. Geological Survey has prepared Landsat-derived land cover products in a variety of formats and classification schemes under cooperative agreements with Federal and State resource management agencies in Alaska. In 1987, a prototype standard Alaska land cover classification scheme using U.S. Geological Survey 1:250,000-scale quadrangles as a base was reviewed by Federal and State agencies in Alaska. It was decided to prepare standard Alaska land cover products during 1989-1992 only for the areas of greatest interest to users, rather than of the entire State. To date, 14 1:250,000-scale Alaska land-cover classifications are complete.

HYDROGRAPHY AND OCEANOGRAPHY

The National Ocean Service is charged with the primary responsibility of providing accurate and timely maps, charts, and related products to improve the efficiency and safety of marine transportation, offshore engineering, coastal zone management, naval operations, and recreational activities. During the past year, bathymetric surveys were conducted in Pacific waters for the Exclusive Economic Zone program; hydrographic surveys were conducted in Alaska, East Coast, Gulf, Great Lakes, and California waters; photogrammetric missions that support the charting programs were also applied to many other diverse and novel problems; and new nautical charts were issued.

The Defense Mapping Agency has the responsibility to provide nautical and marine navigational data in areas outside U.S. waters for national defense and to worldwide merchant marine and private vessel operators.

Hydrographic Surveys

In conjunction with the Naval Oceanographic Office (NAVOCEANO), the Defense Mapping Agency has continued in its pursuit of improving nautical charting coverage of Asian waters for the sake of safety of navigation. Cooperative surveying and charting programs with Indonesia and the Republic of Korea have provided excellent hydrographic data and are contributing to the production of new charts by host nation charting agencies.

Hydrographic surveys accomplished by the National Ocean Service during the reporting period employed six ships and three field party units in the following areas: southern Alaska peninsula; Togiak Bay, Alaska; Icy Strait, Alaska; Frederick Sound, Alaska; Pelican Harbor, Alaska; approaches to Sitka Harbor, Alaska; Sweeper Cove, Adak Island, Alaska; Carquinez Strait, California; Sacramento River, California; Huntington Beach, California; southwest Texas coast; Corpus Christi and Aransas Bays, Texas; approaches to Cameron, Louisiana, and Sabine, Texas; approaches to Biloxi and Pascagoula, Mississippi; Choctawhatchee Bay, Florida; St. Andrew Bay, Florida; Chesapeake Bay Entrance, Virginia; offshore New Jersey coast; Kill Van Kull, New Jersey; New York Bight; western Long Island Sound, New York and Connecticut; southern New England coast, New York, Connecticut, and Rhode Island; and St. Marys River, Michigan.

Hydrographic Data Acquisition and Processing System (HDAPS)

Implementation of NOAA's Hydrographic Data Acquisition and Processing System (HDAPS) progressed in 1989. New automated data acquisition and processing systems have replaced the old HYDROPLOT systems on all hydrographic field units. HDAPS was designed to acquire and field process data in support of basic hydrographic and side scan sonar surveys. Six field units (ships and field parties) which include 16 data acquisition platforms now have HDAPS capability. The types of survey vessels with HDAPS capability range from the 221-ft NOAA Ship RAINIER and its four launches to 21-foot MonArks used by mobile field parties.

HDAPS employs two types of data acquisition systems (DAS). DAS used by ships and 30-ft Jensen launches are configured around Hewlett-Packard Series 9000 Model 300 computers. Currently, ships are equipped the HP-340C (16 inch color monitor) while launches are outfitted with the HP-340M (17-inch monochrome monitors). Peripherals include an HP 9153C 20 mbyte hard disk with high density floppy, a ZETA 824 8-pen color plotter, and an HP printer. Navitronic's Hyflex 1000 is the intelligent interface between sensors and computer. Currently the HP-based DAS can accommodate sensor data from the Raytheon DSF-6000N echo sounder, the EG&G Model 260 side scan sonar, the Hippy 120C Heave, Roll, and Pitch sensor, the Motorola Falcon 484, the Motorola Eagle GPS, CUBIC ARGO DM54 positioning system, and various types of gyrocompasses if the vessel is so equipped.

The HP data acquisition software has color graphic features to assist the hydrographer. Data can be recorded continuously at one second intervals. Data are logged in RAM and then downloaded to a high density floppy disk where at a later time it is uploaded to the data processing system.

The DAS employed by the field parties on small boats is based on a PC-type computer. The computer, Hyflex, and sensors are all powered by either 24 or 12 volts. The system can accommodate the Falcon 484, the Krupp-Atlas Polarfix, the DE-719B echo sounder with Odom Digitrace, the Innerspace 448 echo sounder, and the EG&G 260 side scan sonar. Data are logged on to a hard disk and then downloaded to a floppy. During this process the data are converted from a PC format into an HP format.

The processing system is an HP-340C and can process data acquired from an HP-DAS or a PC-DAS. Data are uploaded via floppy disk on to a 300 mbyte hard drive. Graphic editing, listing, and plotting of data can then be performed. Upon completion of processing, the data are transmitted to the marine centers for verification via 32-track tape.

During 1990, HDAPS software development is focusing on methods for increasing data processing efficiency. Enhancements have been made to the side scan sonar contact file, sounding edit functions, position recomputation function, and plotting routines. In addition, Automated Wreck and Obstruction Information System (AWOIS) data have been incorporated into the HDAPS digital data base.

The U.S. Army Corps of Engineers (Coastal Engineering Research Center of the Waterways Experiment Station in Vicksburg, MS) has contracted with Optech, Inc. (Toronto, Ontario) to provide an airborne laser hydrography system. This SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) system, to be deployed in a Bell 212 helicopter, is to be delivered and tested in the summer of 1992. Differential GPS will be used for positioning. The laser fires 200 pulses per second into a scanner which provides a broad, uniformly sampled swath of soundings under the aircraft. The "conceptual design" phase was successfully completed in 1989; detailed design and construction is underway. The plan is to "privatize" the system so that surveys can be provided by a commercial contractor. The "Field Working Group," an ad hoc committee composed of representatives with operational hydrographic experience from the various Corps regions, has furnished inputs to the design process and is very

supportive in its enthusiasm for using the system after testing and shakedown. NOAA is providing support in the areas of hardware and software design and field testing.

Hydrographic Applications of Satellite Data and Imagery

The Defense Mapping Agency is utilizing Landsat imagery in a number of ways to enhance production, maintenance, and data collection efforts. For example, analog Landsat Multispectral Scanner imagery of shallow seas is being used to locate and validate reported navigational hazards. It is also used in the compilation of medium- and small-scale hydrographic charts and as a planning tool for hydrographic surveys.

Digital Landsat data are being used to analyze areas for hydrographic survey planning graphics. In areas with uniform bottom reflectivity, Multispectral Scanner-derived relative depth information has an accuracy within 10 percent of the depth measured. Over mixed bottom types, its use is limited because only one band (green) has effective water penetration.

Mapping the Exclusive Economic Zone (EEZ)

On March 10, 1983, a significant step was taken by the United States with respect to the exploration and management of both living and non-living marine resources when the President proclaimed the U.S. Exclusive Economic Zone. This zone encompasses 3.4 million square nautical miles of the ocean and seafloor within 200 nautical miles of the U.S. coastline. It includes not only the United States, but also its territories. The National Ocean Service has established a major program to determine the characteristics and resources within the EEZ by utilizing modern survey techniques to provide high-resolution bathymetric maps of areas rich in resource potential.

A joint office has been formed between the National Ocean Service and the U.S. Geological Survey to coordinate the EEZ mapping and research activities of both parent agencies. The U.S. Geological Survey provides copies of imagery data that they have acquired which the National Ocean Service uses for planning and evaluation. The National Ocean Service, in turn, provides the U.S. Geological Survey with detailed bathymetry to support geological interpretation of the seafloor.

Multibeam swath sonar systems are currently installed on four NOAA ships, with plans to equip one more in fiscal year 1992. The NOAA Ship WHITING is equipped with the Hydrochart II Swath Survey System, and surveys water depths between 150 and 1000 meters. The NOAA Ships SURVEYOR, DISCOVERER, and MT. MITCHELL are equipped with the Sea Beam system and can survey areas where the depths range from 600 to 11,000 meters. Thus all of the continental shelf, slope, and upper rise are covered, as well as the deeper areas of the U.S. EEZ such as the Aleutian and Puerto Rico trenches.

More than 80,000 square nautical miles of the EEZ off the Alaska, Washington, Oregon, California, Hawaii, Louisiana, Texas and Virginia, coasts have been surveyed to date. These multibeam systems provide 100-percent coverage of the seafloor, yielding details never revealed before in the U.S. continental shelf

and slope areas. Navigational use of the Global Positioning System to calibrate land-based navigation systems has resulted in a significant increase in ship productivity. Starfix, another satellite based navigation system, has been used almost exclusively in the Gulf of Mexico with great success. Deployment of the full Global Positioning System satellite constellation by the Department of Defense will be critical to completion of the EEZ surveys and will be much less expansive to operate then Starfix.

In 1989, the Department of Defense rescinded its objection to the release of full resolution multibeam data for most geographic areas (97 percent of the EEZ). Since that time, twelve 1:100,000-scale multibeam bathymetric maps have been published. Plans are underway for the orderly dissemination of digital data beginning in fiscal year 1991.

New Charting Products

One new chart was issued in 1990 covering the San Joaquin River and the Stockton deep-water channel from Medford Island to Stockton, California. NOAA now has a total of 987 charts on issue, of which 470 were published as new editions. Of these, 158 depict the 12-mile limit (formerly the contiguous zone, now the territorial sea), 56 show the 200-mile Exclusive Economic Zone limit, 28 show the Natural Resources Boundary (3-league limit), 282 depict LORAN-C, and 24 contain OMEGA navigational information.

Implementation of the new adjustment of the NAD 83 in the nautical charting program began in May 1985. This adjustment involves shifting the existing charted projection and/or adding datum reference and transformation notes to nautical charts. Through the end of fiscal year 1990, 670 charts had been adjusted to NAD 83.

The Defense Mapping Agency's "Notice to Mariners" is a weekly publication issued to advise mariners of matters affecting navigational safety, including new hydrographic discoveries, changes in channels, and modifications to navigational aids. It presents corrective information affecting charts as well as "Coast Pilots," "Sailing Directions," "Fleet Guides," catalogs and nautical charts, "Light Lists," "Radio Navigation Aids," and such other publications that from time to time require updating. The "Notice to Mariners" is produced in an easy to use format with the aid of automated data processing and typesetting equipment, thus minimizing production costs and expediting dissemination. "Sailing Directions" are designed to assist the navigator in planning a voyage of any extent, particularly if it involves an ocean passage. This worldwide series of Defense Mapping Agency publications is compiled by ocean basin, i.e., North Atlantic, South Pacific, Indian Ocean, etc. A planning guide for each area describes oceanography, meteorology, countries, and routes, and is accompanied by two or more enroute publications describing approach and coastal information. The group consists of 46 publications and is designed for modern deep-draft ships provided with electronic navigational and communication equipment. Graphic directional displays supplement textual material and provide mariners with recommendations for approaches to channels, harbors, and anchorages. Photographs, coastline displays, and navigational aid drawings are also used to assist in the identification of landmarks.

Nautical Chart Manual

Editing of the Nautical Chart Manual (seventh edition) is nearing completion. This new edition contains 11 chapters outlining current NOS nautical charting procedures, specifications and standards. Chart features and symbols such as soundings, depth curves, landmarks, land contours and navigational aids are discussed in detail.

The seventh edition includes historical information, NOS general policy guidelines, an overview of NOS internal organizational structure and an outline of the NOS relationship with international charting agencies.

Metric equivalent values are included with all specifications throughout the manual.

A comprehensive glossary of nautical charting and navigational terms and an appendix of many useful, illustrations, diagrams and tables completes the 7th edition.

Photogrammetric Surveys

The photogrammetric surveying mission of NOAA, performed by the Photogrammetry Branch, provides new coastal and special survey data in graphic and digital form, and associated information for the production of nautical and aeronautical products. Photogrammetric survey data, and aerial photographs are available to other federal, state and local agencies, and the public. Program activities include aerial photogrammetric surveys, coastal mapping, shoreline surveys, location of aids to navigation, nautical chart revisions, airport obstruction surveys, obstruction chart production, submerged aquatic vegetation mapping, marine sanctuary boundary demarkation, glacier mapping and Alaska Boundary Working Group projects.

During the year, two air photo missions supply the necessary photographs to meet the requirements for photogrammetric survey projects for the following year and beyond. Airport photography is secured throughout the conterminous United States, while aerial photographs required for new shoreline mapping during fiscal year 1991 were acquired in Alaska, Texas, Virginia, Michigan, Wisconsin, Ohio, and North Carolina.

Aerial photographic surveys are also completed in support of several reimbursable projects. The projects included highway photography for the Alaska Department of Transportation; photography of the Columbia, Taku, and Wolverine Glaciers for the Ice and Climate Office, USGS; photography of Bulkana and Prince William Sound, Alaska, for the U.S. Bureau of Land Management; and selected photographic coverage in the Gulf of Alaska for the Alaska Boundary Working Group and the Mineral Management Service, Department of Interior.

In 1987, the Office of Charting and Geodetic Services agreed to assist the National Marine Fisheries Service with their project to inventory the submerged aquatic vegetation of the Core, Pamlico, Albemarle, and Currituck Sounds of North Carolina. Core Sound was photographed in 1987. Albemarle and

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Currituck Sounds were photographed in 1990, and planning is in progress for photographing Pamlico Sound in 1991. Aerial photographs can capture the location and extent of submerged seagrass quickly and accurately. Ultimately, the extent, distribution, and density of the submerged aquatic vegetation will be mapped. These maps will be used as a research tool to better understand the environment of this area and as a base line study tool from which comparison studies can be made in the future.

Total surveying and mapping accomplishments for fiscal year 1990 include 129 airport surveys, 44 special navigational aid surveys, publishing 166 Airport Obstruction Charts, 160 Obstruction Data Sheets, and completing 9 shoreline mapping projects consisting of 70 maps. The shoreline mapping projects (70 registered maps) provide coverage in the following areas: South Carolina (26), Alaska (9), Texas (9), and Michigan (26).

The Global Positioning System (GPS) was utilized in an increasing trend for the establishment of horizontal control stations. Nearly 75 percent of the control established between March and October was accomplished through the utilization of GPS. GPS controlled photogrammetry took on a new meaning this year. Not only is the targeted control positioned by GPS methods, but also the exposure station of the camera. With the exposure station data applied to the photogrammetric process, the amount of ground control and paneling will be reduced on future projects. The Photogrammetry Branch will become more responsive to the mapping needs of NOAA as a result. With a reduction in the requirement for traditional ground control density, periodic coverage of the entire coastline on a 5- to 10-year cycle can be a reality. Two major tests were planned this year in cooperation with the State of North Carolina. The first test demonstrated the capability of calibrating the airborne photogrammetric systems operated by both agencies. The second test demonstrated the practical application of GPS controlled photogrammetry in two practical missions. The implementation of this technology is expected to be phased in over the next two years as the GPS constellation of satellites is put into full operation.

Electronic Navigation

Eight Omega Electronic Navigation stations, namely A-Norway, B-Liberia, C-Hawaii, D-North Dakota, E-Reunion, F-Argentina, G-Australia, and H-Japan, provide worldwide continuous radio-navigation coverage of medium accuracy. Operating at 10 kilohertz of frequency, they provide hyperbolic lines of position computed by phase comparison of very low frequency radio signals. There are 126 Omega Plotting Charts issued in the 7600/7700 series, which are designed to give global coverage on Mercator projection with a scale of 1:2,187,400 overprinted with Omega zero phase-difference contours for standard propagation conditions. On these plotting charts, the Line of Position (LOP) for a corrected receiver reading of a station pair is constructed by graphical linear interpolation between the charted LOP's.

There are 255 Omega lattice tables and 175 Omega Propagation Correction tables (PPC) for the 10.2 kHz transmission frequency. Additionally, there are 75 PPC tables for the 13.6 kHz frequency, and an Omega Coverage Diagram publication giving the positions of the stations, areas of coverage, and accuracy data.

The LORAN-C system consists of long-range, low-frequency (100 kHz) radio-navigation signals for time-difference comparison. There are 17 LORAN-C chains worldwide that comprise a total of 67 stations. There are 23 Additional Secondary Factor correction charts and 14 LORAN-C Reliability Diagrams published by the Defense Mapping Agency. Further, there are 51 LORAN-C lattice tables and 55 Additional Secondary Factor correction tables presently in the system.

AERONAUTICAL CHARTING

The National Ocean Service's aeronautical charting program consists of the compilation, printing, and distribution of charts and digital files of the United States and its territories to meet the requirements of civilian and military aviation. Approximately 10,000 aeronautical charts are produced annually for use by air flights in the National Airspace System. The continuous process of chart and file maintenance is required to support the regularly scheduled update cycle for the program.

The aeronautical charting program is divided into four main activities: visual, instrument, and special products, and digital aeronautical data management.

Visual Program

The visual program produces 182 different charts that provide information to pilots flying under Federal Aviation Administration visual flight rules. These charts are revised every 6 to 12 months, with approximately 2,500,000 copies distributed each year. The following additional tasks were performed by the visual program during fiscal year 1990:

New multi-color Terminal Area Charts for Memphis, Orlando, Phoenix, Salt Lake City, and Tampa were developed and are available to the public. Three-color VFR Flyway Planning Charts for high density areas surrounding Detroit and Phoenix were produced, and a special edition of the Seattle Sectional chart was prepared to depict temporary prohibited airspace due to the 1990 Goodwill Games.

Several helicopter route charts have been revised, and new charts are being planned to accommodate the increased concentration of helicopter activity around major metropolitan areas. In addition, the dimensions of several Terminal Area Charts are being expanded to include the revised and expanded Terminal Control Areas in large metropolitan areas.

Visual aeronautical charts are flight checked once every 3 years by a rotating crew of NOAA Commissioned Officer pilots flying a Government-owned twin engine "Shrike" Commander aircraft. During fiscal year 1990, the flight check program reviewed selected aeronautical sectional charts and their associated terminal area charts, as well as 92 minimum safe altitude warning areas in the conterminous United States. These flight checks contributed more than 1,400 potential base feature changes and in excess of 900 aeronautical changes for chart compilation. More than 243 photographic sites were compiled and 927 obstacles were measured. Of these obstacles, 224 were found to be new obstructions not previously contained in the obstacle data files; 57 obstructions were found to have been dismantled and were therefore relabeled in the current files; and 690 obstacles were reverified for horizontal position and vertical accuracy. This combined photograph and stereoplot operation yielded an outstanding 90.9-percent usable data return. The flight check program permits the resolution of source data inconsistencies and provides pilot input to the compilation and design of visual aeronautical chart products.

Instrument Program

The instrument program provides more than 8,900 charting items and publications that are used by pilots flying under Federal Aviation Administration instrument flight rules. Approximately 7,800,000 copies of instrument charts and publications are distributed annually. Nearly 80 percent of those publications must be revised every 56 days.

To support this effort, a cross reference program was developed in 1986 that lists all terminal charts affected by a data change. The instrument approach procedure Digital Cross Reference File has been enhanced to include special use airspace and takeoff minimums. Additionally, the file supports the Federal Aviation Administration in determining which terminal procedures must be revised.

In 1988, the National Ocean Service eliminated 6,400 secondary plates on instrument approach procedure (IAP) charts and instrument departure charts by compositing the secondary plate with the primary, thereby increasing productivity and reducing costs.

In an effort to maintain high product and service standards in support of contracting the negative maintenance of instrument approach procedure charts, 17 desk guides were written. These reference documents contain detailed specifications, standards, and procedures, and it is the first time that this information has been brought together in one place. The desk guides were used to prepare the performance work statements for management studies and will become a significant portion of the instrument approach procedure negative maintenance contract.

Inertial Navigational System orientation information has been added to the standard terminal arrival charts and to all standard instrument departure charts. The National Ocean Service is on-line to the Federal Aviation Administration Instrument Approach Procedure Automation (IAPA) program data base in Oklahoma City, Oklahoma. Fifty percent of all procedure changes are now generated by IAPA.

During fiscal year 1990, the following accomplishments were realized:

A program was initiated to convert the Enroute Low Altitude Chart series from two to four colors. The Alaska Low Altitude chart series was produced by automated methods, converted to four colors, and printed in January 1990. The U.S. Low Altitude series is in the prototype stage with no release date determined.

Over 1,000 Radar Video Maps (RVMs) were produced for the 233 Federal Aviation Administration facilities being served. The video maps depicted on radar displays are entirely specified by the air traffic control facility. Each map represents an accurate stable representation of the airways, fixes, boundaries, and runway extension lines which meet the unique requirement of each facility.

A new Digital Bright Radar Indicator Tower Equipment (DBRITE) system is being developed by the National Ocean Service. The system will provide for the Video Maps to be generated and displayed digitally. Instead of a 2.3-inch plate, the data will be on a Programmable Read Only Memory (PROM) chip. Hardware is being procured, programs are being written, and the conversion of 1,396 analog RVMs to digital files for loading to the PROMs is underway. The first DBRITE is scheduled for delivery in December 1990.

Publication of a new product called the U.S. Terminal Procedures Publication (TPP) began in December 1990. The TPP combines Standard Instrument Departure Charts, Standard Terminal Arrival Charts, and Instrument Approach Procedure Charts into one product. The TPP consists of 16 volumes and a Change Notice. At the same time, the Terminal Alaska book will become the Alaska Terminal Procedures Publication with a cover similar to the TPPs.

Special Products and Services

The special products and services program provides controller charts, obstruction charts, radar video overlays and digital data, and information on possible airport obstructions. To provide this information, the National Ocean Service maintains an automated data base containing obstacle information and other data. Nearly 2,500 different charts are produced annually, with revision cycles varying from 28 days to 2 years. Approximately 170,000 copies were produced last year. The following are some of the major accomplishments for fiscal year 1990:

Compilation of 212 Federal Aviation Administration-sponsored Minimum Safe Altitude Warning System sites were completed. The project is now directed towards the continuous maintenance at 6-month intervals and recompilation of various sites for relocations and magnetic variation changes.

The Digital Obstacle File has grown to over 60,000 structures affecting air navigation. Heights and locations of these obstructions are continually verified and maintained in a unique digital data base which is available to the public in hardcopy only.

Subscriptions for the National Ocean Service Digital NAVAIDS File has doubled in the past year. The NAVAID file contains data fields including; the NAVAID identifier, name, NAVAID type, geographic positions, frequency, channel, elevation, magnetic variation and the state or country. This data supports both civil and military navigation systems.

The Digital Aeronautical Chart Supplement (DACS) is now available in both hardcopy and digital formats. The DACS is a composite of information used in conjunction with aeronautical charts. Its main function is to provide ground coordinates needed by air traffic controllers, aviation system developers, and the general aviation community for flight planning.

Digital Special Use Airspace Files are currently being prepared. This data base will give ground coordinates necessary for graphic portrayal of regulatory and non-regulatory airspace. Alert areas, prohibited areas, restricted areas, airport radar service areas, transition areas, and control

zones are among this airspace. Completion of this data base is projected for late 1992.

GEOGRAPHIC NAMES

The United States has continued to be active in programs to standardize domestic and foreign geographic names. These programs are carried out under the authority of the interdepartmental U.S. Board on Geographic Names. During the past few years, gazetteers of several States and foreign countries have been published under the direction of the Board. In addition, guidelines on names automation, alphabetic sequencing of names, and other topics related to standardization have been prepared. The Board also has participated in United Nations programs on geographic names, and has provided on-the-job training on geographic names in the past several years to students from Thailand, Indonesia, and China.

The U.S. has inaugurated a program by the United Nations Group of Experts on Geographical Names (UNGEGN) to evaluate how United Nations' resolutions on names are being applied by nations and to determine how UNGEGN programs can assist developing countries more effectively. Several countries have answered a survey on the topic and additional responses are hoped for. Although further information on the topic is required, most responding nations agree that the standardization of names at the international and national levels requires the following steps: National cartographic agencies should support the creation and operation of names authorities, UN regional cartographic conferences should add names issues items to the agenda, and the UN and other international agencies should provide technical training in names standardization at the national and regional level.

The Defense Mapping Agency has initiated a program to convert its file of 4.5 million geographic names of foreign areas to a format suitable for automatic data processing. This work is being carried out in collaboration with the Board on Geographic Names. By 1993, it will be possible to update the geographic names file and publish gazetteers using fully automated methods. In the past 2 years, the Defense Mapping Agency has produced gazetteers of Antarctica, Chad, China, Denmark and the Faroe Islands, Iraq, Jordan, Madagascar, Panama, Peru, Philippines, Senegal, Sudan, Sweden, and Undersea Features.

An automated information system, the Geographic Names Information System (GNIS), was designed by the U.S. Geological Survey in 1975 to meet the need for a data base of official U.S. geographic names. GNIS is presently capable of providing basic information for about 2 million names used in the United States and its territories. During the period of this report, activities at the U.S. Geological Survey have included a number of projects consisting of standardization of geographic names and the development and maintenance of the National Geographic Names Information System. Although the primary purpose of the data base is in support of the mapping activities of the U.S. Geological Survey, a wide variety of users apply the information in situations requiring the use and analysis of geographic names data. The second phase of data compilation is well underway and another two million names will be gathered from a wide variety of sources over the next 10 years.

The GNIS information is available interactively at U.S. Geological Survey information offices nationwide. Special reports and data base searches are

available in addition to standard products for each State and territory. As the official names depository for the United States of America, an automated maintenance program allows continuous updating and addition of material.

Specifically, GNIS staff is involved in a number of research efforts including automation of Board on Geographic Names domestic operations, the development of a microcomputer-based topographic map names data base, and automation of the Antarctic Names file.

In November 1982, the New Jersey volume was published as the first volume of the "National Gazetteer of the United States of America." All volumes of the National Gazetteer will be published as parts of U.S. Geological Survey Professional Paper 1200, including an abridged volume containing names of major places, features, and areas for the United States. Each State gazetteer contains the official name, feature class, official status of the name, county in which it is located, geographic coordinates, elevation of place or feature, and the name of the U.S. Geological Survey topographic map on which the feature is found. Published volumes include New Jersey, Delaware, Kansas, Arizona, Indiana, and South Dakota. Completed State files scheduled to be published include North Dakota, Florida, Alabama, Mississippi, and Utah. State files in preparation include Massachusetts, Pennsylvania, District of Columbia, North Carolina, Tennessee, Missouri, Iowa, Utah, Nevada, and Oregon. The remaining States and territory files will be researched, processed, and scheduled for completion by 1998.

DIGITAL CARTOGRAPHY

The U.S. Geological Survey has collected and archived digital cartographic data from standard U.S. Geological Survey map products and from aerial photographs since 1979 as part of its National Mapping Program (NMP). The U.S. Geological Survey digital cartography program has rapidly become the central focus of the National Mapping Program. Most mapping research within the U.S. Geological Survey is now aimed at expanding automated cartographic data collection, processing, revision, and product generation capabilities, enhancing digital line data by adding feature layers to existing topology, and increasing data utilization through applications employing geographic information systems.

The digital cartography program produces and archives two basic types of data: digital line graphs (DLGs) and digital elevation models (DEMs). Both types are essential elements in the implementation of automated digital revision and product generation procedures being developed. They are also key data layers for numerous land and resource management and geographic information systems applications by Federal, State, and local agencies, and the private sector.

Digital Line Graphs

The Digital Line Graph (DLG) is a digitized map data set representing points, lines, and areas in vector form. The DLGs are topologically structured with identifiers that express the spatial relationships between map features appearing on a printed map. They are also encoded with attributes representing topographic map symbology. DLG data are now derived from the U.S. Geological Survey primary map series at 1:24,000 scale (1:63,360 scale in Alaska), the 1:100,000-scale map series, and the 1:2,000,000-scale sectional maps. DLG data layers now being produced include the Public Land Survey System (PLSS), boundaries, hydrography, transportation, hypsography (contours), manmade features, survey control, vegetative surface cover, and nonvegetative features.

At present, the collection of boundary, hydrography, and transportation DLG data is complete for the entire 1:2,000,000-scale National Atlas sectional map series. Hydrography and transportation data have been collected at 1:100,000 scale for the conterminous United States and Hawaii, with completion of PLSS, boundaries, and hypsography planned for the mid-1990's. At present, about 36,000 DLGs have been prepared and archived for the 1:24,000- and 1:63,360-scale map series.

Digital Elevation Models

The Digital Elevation Model (DEM) is a sampled array of elevation values portrayed at regularly spaced intervals along south to north profiles that are ordered from west to east. The DEMs are referenced horizontally to either a cartesian UTM or to a geographic coordinate system. Units of coverage for DEMs produced by the U.S. Geological Survey include 7.5- and 15-minute blocks for 1:24,000- and 1:63,360-scale quadrangles and 30- x 30-minute blocks from the 1:100,000-scale map series. The U.S. Geological Survey also distributes DEMs produced by the Defense Mapping Agency covering 1- x 1-degree blocks from

the 1:250,000-scale map series. Most 7.5-minute DEM's have been prepared from automated or manual scanning of high-altitude aerial photographs, although they are derived increasingly from digitized map contours.

DEM data referenced to the 1:24,000-scale map series have been produced for about 40 percent of the conterminous United States and Hawaii. Preparation of DEMs reference to the 1:63,360- and 1:100,000-scale series began on a production basis in 1988. Completion of nationwide DEM coverage at the two larger scales is planned for the year 2000. Preparation of DEMs at 1:100,000 scale is presently requirements oriented and no national coverage goal has been established. The Defense Mapping Agency DEM data distributed by the U.S. Geological Survey is available nationwide.

National Digital Cartographic Data Base

Digital cartographic data sets reside in a centralized U.S. Geological Survey archiving and distribution system, the National Digital Cartographic Data Base (NDCDB). The data are stored on magnetic tape in separate DLG and DEM data bases for each major map series. The data are distributed through the U.S. Geological Survey Earth Science Information Center and are available on 9-track tapes at either 1600 or 6250 bpi density. DLG data are distributed in either a standard or optional format. The standard format, which limits topological linkages to line elements only, is oriented toward generating map graphics. The optional format includes linkages for all lines, nodes, and areas. This allows for the creation of a polygon data structure useful in geographic information systems applications. All DEM data are distributed in a fixed block format containing all data elements. U.S. Geological Survey data archiving and distribution activities are being expanded to include other mapping organization data not meeting national data base standards and thematic data referenced to U.S. Geological Survey maps. The development of products on CD-ROM is also underway.

To accelerate the collection of data for the National Digital Cartographic Data Base, the U.S. Geological Survey has entered into cooperative data collection initiatives with other Federal and State agencies and has begun contracting out some phases of data collection to private sector firms. Guidelines have been developed for acceptance of base category DLG data produced by other agencies into the National Digital Cartographic Data Base. One example of a cooperative program between the U.S. Geological Survey and the Bureau of the Census was the completion of 1:100,000-scale hydrography and transportation data nationwide. The data were needed by the Bureau of the Census to support the 1990 Decennial Census of Population and Housing. Production of 1:100,000-scale hypsography data is currently being accelerated by the U.S. Geological Survey under a cost/share agreement with the Defense Mapping Agency. The U.S. Geological Survey is working with the Forest Service to topologically structure and archive large amounts of 1:24,000-scale digital line map data, which the Forest Service is collecting to support geographic information systems development for forest management.

Both the Forest Service and the Bureau of Land Management are now producing large numbers of DEMs to U.S. Geological Survey standards under work/share agreements. All these activities serve to expand the National Digital Carto-

graphic Data Base in support of U.S. Geological Survey digital revision and product generation, to minimize duplication of effort, and to make available to the user community large amounts of quality digital cartographic data for land and resource management and geographic information systems activities.

Advanced Cartographic System Developments

The advent of the computer has changed the focus of mapping requirements in the United States. For more than 40 years the USGS has provided map users with primary quadrangle map coverage of the United States at 1:24,000-scale in the lower 49 States and at 1:63,360-scale in Alaska. Initial national coverage of the graphic products for the lower 49 States was completed in 1990. The Alaska coverage is scheduled for completion by 1991. In recent years, however, it has become apparent that we must also produce digital versions of these maps to support the needs of our computer-oriented society.

In 1979, the USGS received funding appropriations that formally initiated the National Mapping Division's Digital Cartography Program. More recently, the Division has begun a major new system development effort called Mark II that will implement advanced technologies and production procedures to satisfy National Mapping Program requirements through the year 2000. The most critical of these requirements is population of the National Digital Cartographic Data Base (NDCDB) with digital data representing the content of primary map series and other smaller scale series. This data base will serve two major functions: 1) as a central archive for the dissemination of digital data to the user community for information systems analysis, and 2) as a working data base for production and revision of digital and graphic map products.

To accomplish this ambitious digital data base development and population goal, a series of development tasks are being implemented: to expand and improve mass digitization capabilities; to modify data structures to support increased content and access requirements; to develop digital revision capability; to develop product generation capability for standard, derivative and digital products; to improve quality control; and to support program and data management.

Specific requirements for the NDCDB contents and related production processes have been identified in order to satisfy the overall Mark II objectives. These requirements cover sources of data, categories of data, levels of data integration, data revision, data quality, and both digital and graphic products to be produced from the NDCDB.

To evaluate the existing systems and to facilitate the identification of new and improved capabilities, Mark II was divided into four functional components, each addressing a specific portion of the production process. The data production component addresses all phases of data collection, editing, data processing, and quality control prior to entry into the NDCDB. The data base component is developing several levels of data bases: operational data bases to support ongoing mapping center production and product generation requirements, an archival data base to support the NDCDB, other digital data, and sales and distribution of products. The product generation component is

designed to provide the cartographic products required to support the National Mapping Program. The production management component is being designed primarily as a two-way interface between the Mark II production system and existing production systems to meet the program and production requirements of the National Mapping Program.

For procurement purposes, the components are combined into segments. The data production and product generation components have been grouped as the digital cartographic production segment, and the data base and production management components have been grouped as the program and data management segment. These procurements are being conducted under the auspices of the Defense Mapping Agency in a cooperative effort.

Geographic Information Systems

For the past 5 years, geographic information systems (GIS) technology has gone through a period of steady evolutionary development and refinement. Indications are that we may now be at the starting point of an acceleration in the applications curve; revolutionary changes may occur in the next few years. The driving force behind this anticipated change is the availability of increasingly cost-efficient computer hardware, combined with increasingly sophisticated use of digital technology in base map compilation and revision, and a growing capability to integrate, visualize, and model geophysical, geochemical, hydrologic, socioeconomic, demographic and other thematic layers within a common digital geographic context.

The U.S. Geological Survey currently operates about 100 minicomputers nationwide, with 400-500 scientists making daily use of GIS technology. It is anticipated that over the next 5 years the current systems will be phased out and replaced with individual engineering work stations and networked file servers, each having processing speeds 2- to 4-times greater than the present minicomputers. Concurrently, the in-house GIS user community could grow to as many as 2,000-3,000 scientists.

Much of the GIS applications development activity in the next few years will be related to global change research; the National Mapping Division is just beginning what will probably be at least a decade-long effort to characterize the land surface in support of the broader USGS global change research effort. Initial efforts will be directed toward building a base of spatially referenced digital data for modeling carbon, biomass, water, and energy exchange. The "intelligent data base" will provide a built-in capability for rescaling and/or statistically aggregating all appropriate thematic layers. The output from the data base will feed dynamic process models, which may be at scales ranging from field, landscape, region, and continent to global. This effort will require close cooperation with modeling specialists in other disciplines; exploitation of super computers; use of advanced techniques such as fractal analyses, neural networks, artificial intelligence, and automatic discovery; and will entail a significant research role for the academic community.

Currently, the USGS is completing work with the National Center for Health Statistics to integrate data sets never before evaluated in a spatial context.

Environmentally related start up activities include a wetlands restoration, protection, and research initiative; the International Decade for Natural Disaster Reduction; and development of new production techniques for 1:100,000-scale land use/land cover mapping using a combination of aerial photography, existing digital base and thematic data files, manual interpretation, and automatic classification of satellite and other imagery.

Recent prototype developments include digital revision of the 1:500,000-scale New Jersey State base map, with base category, land use, and other thematic data extracted and generalized from existing 1:100,000- and 1:250,000-scale digital files. This project is a significant early component of a major activity that has been initiated to develop techniques for product generation from digital data. Other recent prototypes developed with GIS techniques include a CD-ROM for broad distribution containing 1:2,000,000-scale national data in DLG format; and a soon-to-be completed county-based prototype of base and thematic layers, also for CD-ROM distribution.

In the area of 3-dimensional visualization, a video tape was recently produced showing subsurface geology within an area of the Soviet Union used for atomic testing. The video images were derived from image, seismic, terrain and detonation data, some of it supplied by the Soviets. Ongoing research in 3-dimensional visualization includes: the mapping of urban areas utilizing "what if" analysis and a 50-year look-ahead at infrastructure trends; dynamic time series modeling of the San Francisco (Loma Prieta) earthquake; and stacked display and analysis of hyperspectral data in anticipation of 128-band multispectral data from the EOS satellite.

Development of Rules for Automated Mapping

To meet increasingly sophisticated user requirements for spatial information in both digital and graphic forms, and at the same time develop greater operating effectiveness, the USGS has embarked on a program to modernize the most fundamental aspects of its cartographic data production, data base development, and product generation operations. This program takes advantage of the latest theoretical and technological advances in cartography. To accomplish this goal, implementation specifications are required to explain how the data is described and manipulated. Implementation of an automated product generation capability requires objective standards that are internally consistent, unambiguous, and well documented. Specifications are currently being developed for the 1:24,000-scale map series and include: delineation specifications which describe what the feature looks like on the ground; extraction specifications which describe when a feature is collected from source for inclusion in the data base; representation rules which describe how the feature will be represented in the data base; product specifications which describe when a feature from the data base is included on the graphic; and a variety of product generation rules that provide for symbolization, generalization, conflict detection and resolution, and names and label placement for graphic production.

Digital Line Graph-Enhanced Data Model

With ever-more powerful computer technology available to collect geographic information, the USGS faces a difficult task: to provide users with up-to-date digital data, while at the same time enhancing the structure of that data to meet the needs of a sophisticated user community. No longer is it sufficient in itself to automate the map-making process for reproducing graphics; spatial data users require a data structure that can support complex queries and analysis of thematic information to seek answers to national (and global) problems.

To address this need, the Geological Survey has moved beyond its present Digital Line Graph (DLG) data structure and created a modernized and enhanced version termed DLG-Enhanced (DLG-E). This new structure is feature-based to closely resemble the way humans perceive their physical surroundings. The features shown on a map, such as roads, streams or buildings, are represented by corresponding "features" encoded in the digital file. Over 200 types of features exist in the DLG-E data model, each derived from the types of features portrayed on USGS topographic maps. These features are further described by attributes that define such characteristics as name or function, and relationships that describe such interactions between features as flow through a network or features that bound one another.

Ultimately, all features in the DLG-E world are linked to the spatial components that comprise them: polygons, chains and nodes. The expression of topology occurs at the spatial level in the file, just as is presently the case for existing DLG files. The current DLG files, however, also encode feature-level information at the spatial level through a series of attribute codes attached to each spatial element. This limitation serves to point out the most important advantage of DLG-E: the separation of spatial components from non-spatial components for more flexibility in manipulating the data base.

Although much work remains to be done before DLG-E becomes a reality, work is underway now to develop a prototype DLG-E production system. This prototype system will generate test data sets which will be utilized to further refine the data structure. The DLG-E data model provides USGS with a flexible tool to support the Nation's fast-growing spatial data needs into the next century. DLG-E will continue to evolve as the needs of the data users themselves change.

The Proposed Spatial Data Transfer Standard (SDTS)

In March 1987, the USGS formed the Digital Cartographic Data Standards Task Force (DCDSTF) to develop a single proposed standard for digital cartographic data by merging draft standards developed by the National Committee for Digital Cartographic Data Standards (NCDCDS) and the Standards Working Group of the Federal Interagency Coordinating Committee on Digital Cartography (FICCDC-SWG). Chaired by the USGS and comprised of 15 members (including key architects of the NCDCDS and the FICCDC-SWG draft standards), the DCDSTF met on four occasions during the summer of 1987, and in October 1987 issued a merged document titled "The Proposed Standard for Digital Cartographic Data"

that was subsequently published in the January 1988 issue of The American Cartographer.

To develop the merged document, the DCDSTF adopted NCDCDS Report 8, "A Draft Proposed Standard for Digital Cartographic Data," as a baseline and incorporated desirable characteristics of the Federal Geographic Exchange Format developed by the FICCDC. The resulting proposed standard consists of four components: (1) Definitions and References, containing definitions of fundamental cartographic objects that serve as conceptual building blocks for the standard; (2) Transfer Specification, describing the logical file structure for the transfer of the data; (3) Data Quality, outlining the form of a quality report; and (4) Cartographic Features, presenting a model for classifying and defining cartographic features, along with an initial set of proposed standard definitions.

The prescribed method of implementation of the proposed standard is the standard specification for a data descriptive file for information interchange (ISO 8211), which was adopted in 1985 by the International Organization for Standardization (ISO), and which is also an American National Standards Institute (ANSI/ISO 8211) and a Federal Information Processing Standard (FIPS PUB 123).

Since the publication of The American Cartographer, the effort to finalize the standard has been coordinated by the USGS. A Technical Review Board (TRB) was appointed and given the responsibility for finalizing the standard for promotion to NIST for approval as a FIPS. The board includes representatives from the Federal Government, the commercial sector, and the university community.

Empirical testing and refinement have been the focus of SDTS development activities during the period 1988-1990. The USGS, the Bureau of the Census, and the Defense Mapping Agency participated in phase 1 testing by encoding test data into the format specified by the standard. Encoded files were exchanged and decoded by each participating agency. Suggested improvements resulting from this exercise were documented and presented to the TRB for evaluation. In the second phase of testing, other Federal agencies and private sector organizations were asked to test the concepts presented in the SDTS (as revised following phase 1 testing) and report their findings. The suggestions and recommendations raised during phase 2 testing were presented to the TRB, and were utilized to further revise the SDTS prior to formal submittal for consideration as a Federal Information Processing Standard.

The SDTS was delivered to the National Institute of Standards and Technology in July 1990 for consideration as a Federal Information Processing Standard. Ongoing activities include: 1) review of SDTS for conformance to FIPS and ANSI style; 2) development of conformance criteria and procedures through an agreement with NIST; and 3) development of a suite of software to support requirements including: file browsing and structural summary, diagnostic capabilities, plotting and display, and possible conversion to other file formats such as relational data base structures. This includes rules development, software support, and procedures for testing to determine if data sets produced by agency and vendor systems conform to SDTS specifications.

Conformance testing may also include evaluation of receiving systems in terms of ability to process SDTS data.

Federal Coordination

The U.S. Geological Survey chairs two major Federal-level digital cartography coordinating committees. The Interior Digital Cartography Coordinating Committee (IDCCC) was established in 1982 by the Secretary of the Interior to provide a forum within the Department of the Interior to facilitate coordination in collecting digital cartographic data and to realize multipurpose use and exchange of data. The IDCCC consists of a steering committee with representatives from each of the Interior bureaus, three working groups, and two regional subcommittees.

The Federal Interagency Coordinating Committee on Digital Cartography (FICCDC) was established in 198- at the request of the Director of the Office of Management and Budget. The FICCDC is comprised of a steering committee with representatives from 12 Federal departments and independent agencies, five working groups, and one task group. The purpose of the FICCDC is to recommend procedures and programs that would facilitate coordination of Federal agencies' digital cartographic activities and to establish and promulgate standards and specifications for the production of digital cartographic data. In 1990, the FICCDC proposed the revision of Office of Management and Budget Circular A-16. The revised Circular, recently approved by the Office of Management and Budget, expands the breadth of coordination of spatial data, assigns Government-wide leadership roles to Federal departments for coordinating these data, and establishes a new interagency coordinating committee, named the Federal Geographic Data Committee, that has the objective of promoting the coordinated development, use, sharing, and dissemination of surveying, mapping, and related spatial data. The new committee will supersede the FICCDC.

Other Mapping Organization Data

The U.S. Geological Survey has in place "Guidelines for Acceptance of Digital Cartographic Data into the National Digital Cartographic Data Base" with the intent of facilitating and encouraging cooperative efforts among Federal, State, and other organizations to produce and share digital cartographic data. A variety of interagency agreements now exists for exchanging digital data, including an agreement with the Forest Service for producing and (or) exchanging DEM and DLG data. Other similar examples include agreements with the Bureau of Land Management, the Defense Mapping Agency, the State of Washington Department of Natural Resources, and the Idaho Transportation Department.

GLOBAL CHANGE: CHALLENGES FOR GEOGRAPHY

The U.S. Global Change Research Program (USGCRP) is a coordinated effort involving seven departments and agencies of the U.S. Government and numerous academic research institutions. It sponsors studies of the atmosphere, oceans, and land surface; the physical, chemical, and biological processes that occur in these environments; and the linkages between them. The program includes components of (1) observation and monitoring; (2) enhancement of scientific understanding; (3) development of models, especially predictive models; and (4) management of environmental data. The program emphasizes interdisciplinary studies and development of an integrated understanding of large-scale environmental processes and causes of environmental change.

Environmental process models exist in two forms: (1) global models that treat land processes as functional "boxes" with little or no allowance for the diversity, structure, or location-dependence of land characteristics and processes; and (2) site- to landscape-scale models that better account for geographic reality but which are limited in geographic extent. The National Mapping Division is contributing to environmental modeling with the following activities:

1.1 Land Characterization, which develops geographic data resources for use in landscape- to regional-scale environmental modeling. These efforts are linked to academic studies of Long Term Ecological Research (LTER) sites funded principally by the National Science Foundation and to basin-scale hydrologic studies being undertaken by the Water Resources Division of USGS. The strategy of this effort is to expand geographic coverage from a small set of LTER-site "nuclei" to regional coverages that will, in approximately a decade, merge to provide continental-scale coverage. GIS software systems will be ported to the most capable available computer environments in support of this work.

1.2 Pilot Data-Set Development, which generates continental-scale data sets of satellite greenness-index observations, soil maps, and other information that will help global "box" modelers to incorporate greater geographic realism into their models. This information will combine naturally with data from activity 1.1 when its geographic coverage expands to a sufficient extent.

In both of the foregoing activities, the Division is developing methods for obtaining and managing geographic information at multiple scales and linking land-characteristics statistics between those scales.

The availability of geographic data to the global-change research community is sometimes limited by difficulty of access to information about data holdings, data quality, and other "metadata." Community access to data is being improved by the following activity:

2. Global Land Information System, which will provide information about geographic data holdings via network access from a personal-computer environment. Flexible queries by date, location, and data type and

quality will be supported and some classes of information will be portrayed graphically on the user's computer.

The National Mapping Division is also working to preserve a unique and consistent set of observations of land characteristics and conditions obtained over the last 20 years:

3. Landsat data conversion is an effort to convert the Landsat multispectral scanner and thematic mapper data archive from high-density tape to longer-life, computer-compatible media.

APPENDIXES

The following appendixes contain information on selected digital cartographic capabilities and systems supplied by the principal Federal agencies who have contributed to this report. The agencies may be contacted for additional information on their activities.

APPENDIX I

Defense Mapping Agency Automated Cartography

The Defense Mapping Agency is undergoing a mandatory conversion of present production processes. This program, called the Digital Production System, is implemented in two phases, MARK 85 and MARK 90.

The first phase, MARK 85, modified and supplemented existing production equipment to provide an interim capability to exploit new source materials. The MARK 85 has six segments that support the existing Defense Mapping Agency production procedures and operates primarily in a hardcopy environment.

The MARK 85 provides computer software to implement photogrammetric models to a variety of existing Defense Mapping Agency hardware as well as to modern inter-active workstations capable of semiautomatic terrain and interactive feature extraction. This system also provides for the inventory of all Defense Mapping Agency source holdings. In addition, MARK 85 provides the functionality for production programming and planning for all of the Defense Mapping Agency.

The second phase, MARK 90, provides the end-to-end digital production system that replaces most of the Defense Mapping Agency production line and significantly enhances Defense Mapping Agency productivity. The MARK 90 is being developed in five segments. When linked together, they provide a fully integrated production capability. Three segments of the MARK 85 are included in the MARK 90 development to support required production capabilities.

The MARK 90, to be delivered in 1992, will build upon the MARK 85 to further enhance production and program management for the Defense Mapping Agency. This system will accomplish automatic terrain extraction and semiautomated feature extraction. Feature delineation and attribution are facilitated using knowledge-based engineering. All extracted data will be stored in a data base where these data can be generalized and segregated to produce a defined set of Defense Mapping Agency products.

APPENDIX II

Mark II: The Next Step in Digital Systems Development at the U.S. Geological Survey

The National Mapping Division, U.S. Geological Survey, has begun a major new system development effort, Mark II. The goal of this program is to implement advanced technologies and production procedures that will satisfy project requirements of the National Mapping Program through the year 2000. At that time, the National Digital Cartographic Data Base will be fully operational, with its contents based essentially on digital data. These data will represent the 7.5-minute, 1:24,000-scale map series, as well as other smaller scale series, and will be the central focus of the Division's mapping activities.

To accomplish this ambitious goal, a series of development tasks are being implemented to (1) expand and improve mass digitization capabilities, (2) modify data structures to support increased content and access requirements, (3) develop digital revision capability, (4) develop product generation capability for standard, derivative, and digital products, (5) improve quality control, and (6) support advanced analysis and applications. Development of the Mark II system has begun, and implementation over the next few years will lead to full production of the 1:24,000-scale digital data collection in the mid-1990's.

The design, development, and implementation of the Mark II system represents a major development activity within the Geological Survey. It will exploit state-of-the-art mapping technology, resulting in a highly responsive digital cartographic production system. The National Mapping Division believes that the timing of this effort is appropriate and necessary to meet requirements, and that the state of available technology will support the effort. The Division also feels that the future needs of the users of these data will be fully met.

The development of the Mark II system will assure that the long-term goal will be met, that the National Digital Cartographic Data Base will support the product and process requirements of the National Mapping Program. Attainment of this goal will allow the Division to be responsive to national requirements for up-to-date cartographic data and map products that are produced more quickly and efficiently.

APPENDIX III

National Ocean Service Automated Chart Production

Nautical Charts: In September 1988, the Nautical Charting Division (NCD) of the National Ocean Service (NOS) contracted with Intergraph, Inc. to design and develop the second generation automated nautical charting system. With this contract, NCD has embarked on a modernization effort that will eventually lead to the automated production of its entire suite of nautical charting products.

A detailed design of the proposed system is currently underway. This design is being done by an onsite Intergraph design team working under the guidance of the NOS Automated Nautical Charting System II (ANCS II) project team. Although details of the design are not complete, the following describes the general architecture of the system.

Under ANCS II, data management and product generation will be accomplished at Intergraph work stations. Plans call for about 40 workstations, consisting of a mix of Intergraph's 200 series and 300 series workstations, to process a variety of different types and sizes of documents and jobs. The 300 series machines support WYSIWYG graphic displays and any other cartographic functions that are computationally intensive. The 200 series machines will support less complex graphics and functions. Some of the workstations in the ANCS II system will be of the 200 series InterPro variety. These are desk top, single screen machines. However, the system will also contain a number of the 300 series InterView variety (dual screen with full size digitizing tables). These will support collection of data for data base maintenance. Unlike the equipment used in the earlier Automated Information System, both series of machines can exist in a normal office environment and will eventually be distributed throughout the work space currently occupied by NCD's Mapping and Charting Branch. The workstations will be linked together using Ethernet; coaxial cable is used within individual buildings and fiber optic cable between buildings. The final ANCS II hardware configuration will also contain a number of InterServe central storage devices. These will serve as the controllers and data storage nodes for the data within the system and will also serve as controllers for on-line plotting capabilities and other peripherals. All the hardware share identical architecture and are based on Intergraph's CLIPPER chip.

The detailed design phase of the ANCS II project was completed in July 1990, and the resultant design is undergoing Critical Design Review (CRD). During CRD, design issues that emerge will be resolved. This phase will be followed by development and system testing which will include a 6-month trial production phase involving 50 of the 1,000 NOS charts, system acceptance, implementation within the NCD, and eventual expansion to include all NOS nautical charts and related products. Initial operating capability for the system is scheduled for 1992.

Aeronautical Charts: Aeronautical charting requirements have grown steadily over the past decade while the number of ACD employees has decreased, even

though most of ACD's products must be revised every 56 days. To meet these growing demands, ACD has been applying automated techniques to a number of cartographic functions. The Aeronautical Chart Automation Project (ACAP) is dedicated to improving the efficiency of the cartographic process through automation. Although similarities exist between the automation efforts in both nautical and aeronautical charting, each has unique requirements that can best be met by two somewhat different approaches to automation. For the present, each system will evolve essentially independent of the other. Common use of compatible equipment will be utilized whenever possible.

The goal of the ACAP project is to produce and implement an overall system containing a central host computer interfaced with graphic workstations and special digitizing subsystems. Unique digitizing capability is important to the overall system concept with regard to later upgrades of the host computer. Past experience has shown that specially configured and modified computers, and their unique operating systems that frequently incorporated turnkey digitizing systems, can be impossible to expand or upgrade at a later date. The current ACAP plan envisions the modular implementation of a comprehensive system in support of all major aeronautical charting products. This includes the automated production of chart overlays suitable for direct use in the reproduction process.

Although the automation of the topographic base for large charts was never a goal, the Aeronautical Information Data Base of ACAP will be capable of directly supporting graphic overlay compilation, overlay production, and generalized support for all products.

Realization of the ACAP concept will allow for the automated production of the Air Route Pilot System, Quality Control Plot System, radar video maps, IAP Management Control System, Controller Chart System, IAP Chart System, enroute chart automation, SID/STAR chart implementation, AIB Compaid automation, and Visual Chart Automated Assistance System. The new system is installed at the Rockville, Maryland, site of ACD and supports 20 alphanumeric terminals, five graphic workstations, and two precision proof plotters.

The final system configuration includes a Digital Equipment Corporation (DEC) VAX 750 and a VAX 780. Amortization of the original purchase cost over a 3-year period will result in considerable cost savings over the cost of the timesharing charges on the National Oceanic and Atmospheric Administration UNIVAC. The VAX mainframe CPU's will support more than 40 alphanumeric terminals, plus more than 20 interactive graphic workstations. Included in the hardware will be five precision proof plotters, and ultimately a high quality chart output device.